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Correlation of Different Physical Properties of Cohesive Soil

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***Abstract*— The correlation of different properties of soil play an important role in many practices for soil and foundation engineering. It may not be possible to conduct large number of time consuming shear and consolidation tests, where, the structure is built on a thick clayey deposit. Again, there are also difficulties to recover undisturbed soil samples from very stiff to hard clayey layer as well as very soft clay layer. But the strength of these layers are essential to be known for design purpose. Under such conditions, correlations are important to estimate the engineering properties of soil. Kolkata being one of the largest metropolises in India and mostly founded on alluvial deposit, has been taken into consideration for our study.**

In this study, laboratory test results and borehole logs from many parts of Kolkata and Rajarhat-Newtown area, provided by various private companies have been considered. The available collected data of boreholes from Kolkata and New Town area gave all the parameters required to make the equations and their graphical representation. Since the process of consolidation test, shear strength test, triaxial test or unconfined compression strength test etc. are time consuming, the correlation of different properties of soil play an important role for design purposes.

***Index Terms*— Correlations of different properties of soil, alluvial, consolidation test, unconfined compression strength test..**

I. Introduction

Kolkata and New Town region (Rajarhat) are located in the eastern part of India. It has spread linearly along the banks of the Hooghly River. In most of the Indo-Gangetic plain, the soil type is predominantly alluvial. Large numbers of constructions are going on in and around Kolkata. For this, huge number of time consuming shear and consolidation test are to be conducted, specially, where, the structure is built on a thick clayey deposit. In this situation, correlation of different properties of soil play an important role for several civil engineering construction purposes. For this, laboratory test results and borehole logs data provided by private companies, from many parts of Kolkata and Rajarhat areas were collected. Shear strength is mostly dependent on sample disturbance and collection of undisturbed sample should be given as prime importance in geotechnical exploration work. In this study, The relationship of the different soil properties such as clay percentage, plasticity index with compression index (Cc), undrained shear strength (C) and unconfined compression strength (UCS) have been developed.

II. OBJECTIVES AND SCOPE OF WORK

The objective of this study is to develop the correlation between different physical properties of cohesive soil since the properties of soil play an important role in many practices for geotechnical engineering. Geotechnical engineers consider the shear strength of a soil as one of its most important engineering properties. Here the work is solely based on the relationship between percentage of clay with undrained shear strength, unconfined compression strength value and compression index, as well as plasticity index with undrained shear strength, unconfined compression strength and compression index. Further, the obtained results are validated with some other bore log data from other location. The in-situ characteristics of the cohesive soil are difficult to predict with disturbed sample of soil.

Undertaking all the possibilities the scope of the work are discussed here.

- Identification of the location in and around New Town region (Rajarhat). Part of Kolkata, West Bengal.
- Collection of various soil properties from the available bore log data collected from various sources.
- To plot the values of undrained shear strength (Cu) , unconfined compression strength (UCS) and compression index (Cc) with respect to percentage of clay and plasticity index (PI%). And to establish a set equations for the each and every plotting respectively.
- Validation of the obtained results with some other bore log data from other location.

III. METHODOLOGY

In order to develop the correlation between percentage of clay and plasticity index with UCS, Cc and Cu, laboratory test results and borehole logs data provided by private companies, from many parts of Kolkata and Rajarhat areas were collected.

Statistical regression analysis by microsoft excel software is used here for developing correlations by plotting graphs between clay% vs Cc value, clay% vs Cu value, clay% vs UCS value. Similarly the relations are also done between PI% vs Cc, PI% vs Cu, PI% vs UCS. Regression analysis by the method of least square method is performed between dependent and independent parameter. By using this method, a best-fit power curve is drawn for developing the correlations. Three well known statistical indices (a) Coefficient of determination, i.e. R^2, (b) the trend line equation and (c) Coefficient of Correlation are used in order to compare the performance. It is to be noted down that closer the value R^2 to 1.00, better is the correlation performance.

IV. RESULTS AND DISCUSSIONS

As stated above, statistical regression analysis is performed for developing the correlations between clay% and PI% with UCS, Cc and Cu values of soil. The plotting of individual graph for individual bore log was correct but to find out the equation and check the horizontality profile, some problems merged up. This conflict was taken care of by making an average value of the borehole data for different layers. Here in

this work we have five layers or sections of borehole depth. The depths are taken as (0-3) m, (3-6)m, (6-9)m, (9-12)m, (12-15)m respectively. Then all the ten values of each of the properties were taken and an average of it was made and then the graph was plotted. Beyond 15m depth we couldn't proceed since there was not enough data of Cc and Cu around Rajarhat Kolkata area at this depth.

[1] **BORE HOLE DEPTH IS (0-3)M**

Borehole	% of Clay	C_u	**PI (%)**	**UCC**	**Cc**
BH 1	**15.5**	**0.22**	**13.5**	**0.35**	**0.18**
BH 2	**17**	0.31	**12.5**	**0.51**	**0.155**
BH 3	**30.5**	0.2	**30**	**0.4**	**0.2**
BH 4	**16**	0.22	**17**	**0.4**	**0.18**
BH 5	**10**	0.25	**7**	**0.48**	**0.17**
BH 6	**19**	0.23	**20**	**0.4**	**0.19**
BH 7	**20**	0.25	**23**	**0.45**	**0.18**
BH 8	**17**	0.25	**13.5**	**0.4**	**0.18**
BH 9	**10**	0.25	**7**	**0.4**	**0.16**
BH 10	**6.5**	0.28	**6**	**0.5**	**0.16**

For C_u vs Clay% $C_u = -6E\text{-}05x^2 - 0.0003x + 0.2685$……..(1)
For C_u vs PI% $C_u = -5E\text{-}05x^2 - 0.0007x + 0.2703$….(2)
For UCS vs Clay% $q_u = 0.0002x^2 - 0.0102x + 0.5333$…...(3)
For UCS vs PI% $q_u = 0.0002x^2 - 0.01x + 0.5177$ ……(4)
For Cc vs Clay% $C_c = 5E\text{-}06x^2 + 0.0015x + 0.1499$….…..(5)
For Cc vs PI% $C_c = -1E\text{-}06x^2 + 0.0016x + 0.1522$……..(6)

[2] **BORE HOLE DEPTH IS (3-6)M**

Borehole	% of Clay	C_u	**PI (%)**	**UCC**	**Cc**
BH 1	15.5	12.5	0.18	0.25	0.21
BH 2	19.5	12.5	0.22	0.52	0.18
BH 3	33.5	26	0.18	0.35	0.3
BH 4	22	18.5	0.25	0.5	0.2
BH 5	35	26.5	0.25	0.48	0.17
BH 6	44	28	0.16	0.21	0.4
BH 7	18	13	0.12	0.2	0.3
BH 8	38	20	0.16	0.25	0.35
BH 9	9	5	0.155	0.4	0.16
BH 10	5.5	3.5	0	0	0

For C_u vs Clay% $C_u = -0.0002x^2 + 0.0115x + 0.0543$…..(7)
For C_u vs PI% $C_u = -0.0002x^2 + 0.0073x + 0.1161$....(8)
For UCS vs Clay% $q_u = -0.0005x^2 + 0.0219x + 0.1475$….(9)
For UCS vs PI% $q_u = 2E\text{-}05x^2 - 0.0023x + 0.3829$….(10)
For Cc vs Clay% $C_c = 0.0002x^2 - 0.0046x + 0.2266$……(11)
For Cc vs PI% $C_c = -0.0001x^2 + 0.0098x + 0.1182$…..(12)

[3] BORE HOLE DEPTH IS (6-9)M

Borehole	% of Clay	C_u	**PI (%)**	**UCC**	**Cc**
BH 1	22.5	0.135	18.5	**0.2**	**0.28**
BH 2	30	0.11	28	**0.15**	0.3
BH 3	41.5	0.16	29.5	**0.3**	0.4
BH 4	29	0.12	18	**0.18**	0.4
BH 5	40	0.14	25.5	**0.2**	0.36
BH 6	16	0.15	13	**0.24**	0.27
BH 7	42	0.17	27	**0.27**	0.42
BH 8	36.5	0.155	23	**0.22**	0.37
BH 9	6	0	9	**0**	0
BH 10	8	0.2	8	**0.3**	0.2

For C_u vs Clay% $C_u = 0.0002x^2 - 0.0122x + 0.2909$ ….(13)
For C_u vs PI% $C_u = 0.0002x^2 - 0.0063x + 0.1986$ …..(14)
For UCS vs Clay% $q_u = 0.0005x^2 - 0.03x + 0.5896$ ……....(15)
For UCS vs PI% $q_u = 0.0009x^2 - 0.0351x + 0.55$ ……...(16)
For Cc vs Clay% $C_c = -1E\text{-}05x^2 + 0.0059x + 0.1749$ …...(17)
For Cc vs PI% $C_c = -0.0005x^2 + 0.0272x + 0.009$ …..(18)

[4] **BORE HOLE DEPTH IS (9-12)M**

Borehole	% of Clay	C_u	**PI (%)**	**UCC**	**Cc**
BH 1	28	0.105	26	**0**	**0.335**
BH 2	35	0.15	27	**0**	0.3
BH 3	39	0.14	30	**0.25**	0.4
BH 4	35	0.16	23	**0.25**	0.34
BH 5	12	0.15	12	**0.22**	0.28
BH 6	16	0.15	13	**0.24**	0.27
BH 7	42	0.17	27	**0.27**	0.42
BH 8	35	0.15	26	**0.2**	0.4
BH 9	9.5	0.2	7.5	**0.4**	0.18
BH 10	9	0.24	8	**0.35**	0.18

For C_u vs Clay% $C_u = 0.0003x^2 - 0.0147x + 0.3186$……(19)
For C_u vs PI% $C_u = 0.0004x^2 - 0.0161x + 0.3119$……..(20)
For UCS vs Clay% $q_u = 0.0005x^2 - 0.0281x + 0.5588$……(21)
For UCS vs PI% $q_u = 0.0009x^2 - 0.0393x + 0.6046$……(22)
For Cc vs Clay% $C_c = -4E\text{-}05x^2 + 0.008x + 0.1368$……..(23)
For Cc vs PI% $C_c = -0.0003x^2 + 0.0205x + 0.0507$……(24)

[5] **BORE HOLE DEPTH IS (12-15)M**

Borehole	% of Clay	C_u	**PI (%)**	**UCC**	**Cc**
BH 1	26	0.405	25	1.3	0.245
BH 2	35	0.16	23	0.25	0.34
BH 3	12	0.15	12	0.22	0.28
BH 4	36	0.18	20	0.25	0.36
BH 5	39	0.14	28	0.22	0.4
BH 6	13	0.25	13	0.48	0.2
BH 7	6	0.18	8	0.25	21
BH 8	26	0.405	25	1.3	0.245
BH 9	35	0.16	23	0.25	0.34
BH 10	12	0.15	12	0.22	0.28

For C_u vs Clay% $C_u = -0.0007x^2 + 0.033x - 0.0468$………(25)
For C_u vs PI% $C_u = -0.0003x^2 + 0.0138x + 0.0775$……(26)
For UCS vs Clay% $q_u = -0.0031x^2 + 0.143x - 0.7261$………(27)
For UCS vs PI% $q_u = -0.0007x^2 + 0.0408x - 0.0654$……..(28)
For Cc vs Clay% $C_c = 0.0509x^2 - 2.6731x + 30.189$ ……..(29)
For Cc vs PI% $C_c = 0.1246x^2 - 5.118x + 49.234$ ……….(30)

V. VALIDATION

However, after developing the equations all these equations are verified by additional laboratory data which had not been used in developing the equations and the results are found quite satisfactory. This indicates that the developed correlations provide a satisfactory agreement with the actual values.

C_u VS CLAY %

Borehole Depth (m)	Clay (%)	Calculated C-value	Observed C-value
(0 – 3)	13	0.25446	0.3
	10	0.2595	0.18
	18	0.24366	0.3
	12	0.25626	0.2
	12	0.25626	0.2
	4	0.26634	0.05
(3 – 6)	9	0.1416	0.2
	24	0.2151	0.15
(6 – 9)	11	0.1809	0.16
	6	0.2249	0.2
	8	0.2061	0.17
	36	0.1109	0.2
	16	0.1469	0.15
	20	0.1269	0.17

C_u VS PI %

Borehole Depth (m)	PI (%)	Calculated C-value	Observed C-value
(0 – 3)	13	0.25275	0.3
	12	0.2547	0.18
	17	0.24395	0.3
	13	0.25275	0.2
	12	0.2547	0.2
	13	0.25275	0.3
(3 – 6)	10	0.1691	0.2
	28	0.1637	0.15
(6 – 9)	12	0.1518	0.16
	6	0.168	0.2
	8	0.161	0.17
	35	0.2231	0.2
	13	0.1505	0.15
	18	0.15	0.17

UCS VS CLAY %

Borehole Depth (m)	Clay (%)	Calculated UCS-value	Observed UCS-value
(0 – 3)	13	0.4345	0.55
	10	0.4513	0.3
	18	0.4145	0.52
	12	0.4397	0.3
	12	0.4397	0.3
	4	0.4345	0.55
(3 – 6)	9	0.3041	0.32
	24	0.3851	0.31
(6 – 9)	11	0.3201	0.25
	6	0.4276	0.35
	8	0.3816	0.25
	36	0.1576	0.4
	16	0.1896	0.35
	20	0.3201	0.25

UCS VS PI%

Borehole Depth (m)	PI (%)	Calculated UCS-value	Observed UCS-value
(0 – 3)	13	0.4215	0.55
	10	0.4265	0.3
	18	0.4055	0.52
	12	0.4215	0.3
	12	0.4265	0.3
	4	0.4215	0.55
(3 – 6)	10	0.32	0.3619
	28	0.31	0.33418
(6 – 9)	12	0.2584	0.25
	6	0.3718	0.35
	8	0.3268	0.16
	35	0.424	0.4
	18	0.2098	0.35
	12	0.2584	0.25

Cc vs CLAY %

Borehole Depth (m)	Clay (%)	Calculated Cc-value	Observed Cc -value
(0 – 3)	13	0.170245	0.19
	10	0.1654	0.17
	18	0.17852	0.17
	12	0.16862	0.17
	12	0.16862	0.17
	4		
(3 – 6)	9	0.2014	0.18
	24	0.2314	0.26
(6 – 9)	11	0.23859	0.22
	6	0.20994	0.17
	8	0.22146	0.16
	36	0.37434	0.22
	16	0.26674	0.2
	20	0.2889	0.28

Cc vs PI %

Borehole Depth (m)	PI (%)	Calculated Cc-value	Observed Cc -value
(0 – 3)	13	0.172831	0.19
	10	0.171256	0.17
	18	0.179111	0.17
	12	0.172831	0.17
	12	0.171256	0.17
	4		
(3 – 6)	10	0.2062	0.18
	28	0.3142	0.26
(6 – 9)	12	0.2634	0.22
	6	0.1542	0.17
	8	0.1946	0.16
	35	0.3485	0.22
	18	0.2781	0.2
	12	0.3366	0.28

VI. Conclusion

Shear strength is mostly dependent on sample disturbance and collection of undisturbed sample should be given as prime importance in geotechnical exploration work. It may not be possible to conduct unconsolidated undrained shear tests on large number of samples where, say the structure is built on a thick clayey deposit. Again, there are also difficulties to recover undisturbed soil samples from very stiff to hard clayey layer as well as very soft clay layer. But the strength of these layers are essential to be known. Under such condition correlations are important to estimate the engineering properties of soil.

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